Technical Report

Massachusetts Division of Marine Fisheries
Technical Report TR-65

Massachusetts Striped Bass Monitoring Report for 2016

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Commonwealth of Massachusetts
Executive Office of Energy and Environmental Affairs
Department of Fish and Game
Massachusetts Division of Marine Fisheries

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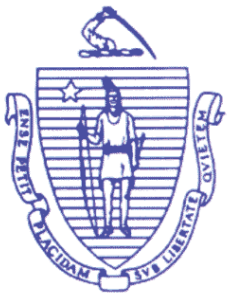

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Commonwealth of Massachusetts
Charles D. Baker, Governor
Executive Office of Energy and Environmental Affairs
Matthew A. Beaton, Secretary
Department of Fish and Game
Ronald Amidon, Commissioner
Massachusetts Division of Marine Fisheries
David E. Pierce, Director

Summary: During 2016, the Massachusetts commercial fishery for striped bass sold about 48,044 fish weighing 938,741 pounds. The recreational fishery harvested about 131,793 striped bass weighing over 2.0 million pounds. Total losses due to recreational fishing (including release mortality) were 332,021 fish weighing over 3.2 million pounds. Combined removals (commercial harvest plus recreational harvest and dead releases) were 380,066 fish weighing over 4.1 million pounds.

Introduction

This report summarizes the commercial and recreational striped bass fisheries conducted in Massachusetts during 2016. Data sources used to characterize the state fisheries come from monitoring programs of the Massachusetts Division of Marine Fisheries (DMF) and National Marine Fisheries Service (NMFS), which are considered to be essential elements of the long-term management approach described in Section 3 of the Atlantic States Marine Fisheries Commission's (ASMFC) Fisheries Management Report No. 41 (Amendment #6 to the Interstate Fishery management Plan for Atlantic Striped Bass (IFMP)).

Commercial Fishery in 2016

Season: June 23–August 18, 2016. Landings were permitted on Monday and Thursday only .

Sold: 938,741 pounds (against a harvest quota of 869,813 pounds). Overage: 68,929 pounds

Allowable Gear Type: Hook and line.

Minimum Size: 34 inches total length.

Trip Limit: 15 fish per day for fishers with a commercial lobster or boat permit and a striped bass endorsement; 2 fish per day for fishers with a commercial individual or rod & reel permit and a striped bass endorsement.

Licensing, Reporting, and Estimation of Landings. To purchase striped bass directly from fishermen, fish dealers are required to obtain special authorization from the DMF in addition to standard seafood dealer permits. Dealer reporting requirement included weekly reporting to the DMF or SAFIS system of all striped bass purchases. If sent to DMF, all landings information is entered into SAFIS by DMF personnel. Following the close of the season, dealers are also required to provide a written transcript consisting of purchase dates, number of fish, pounds of fish, and names and permit numbers of fishermen from whom they purchased. DMF personnel review dealer transactions and correct entries before calculating total landings.

Table 1. Attributes of the Massachusetts striped bass commercial fishery, 1990-2016.

		Purchased			
Year	Season (Fishing Days)	Pounds 000s	Number 000s	Dealer Permits	Fishing Permits
1990	93	160.6	6.3	95	1,498
1991	59	234.8	10.4	92	1,739
1992	39	239.2	11.3	135	1,861
1993	35	262.6	13.0	152	2,056
1994	24	199.6	10.4	150	2,367
1995	57	782.0	41.2	161	3,353
1996	42	696.8	38.3	179	3,801
1997	42	785.9	44.8	173	5,500
1998	28	822.0	45.3	180	5,540
1999	40	788.2	40.8	167	3,578
2000	36	779.7	40.2	137	3,283
2001	29	815.0	40.2	164	4,219
2002	21	924.9	44.9	132	4,598
2003	21	1055.4	55.7	151	4,867
2004	19	1206.3	60.6	130	4,376
2005	22	1104.7	59.5	162	4,159
2006	26	1312.1	69.9	136	3,980
2007	22	1,040.3	54.3	160	3,906
2008	34	1,160.1	61.1	167	3,821
2009	27	1,138.3	59.3	178	4,020
2010	24	1,224.4	60.3	178	3,951
2011	18	1,163.8	56.1	189	3,965
2012	17	1,219.7	61.5	186	3,965
2013	16	1,004.5	58.5	187	4,016
2014	21	1,138.5	56.1	195	3,896
2015	17	865.7	42.2	160	3,864
2016	17	938.7	48.0	173	3,875

Fishermen must have a *MarineFisheries* commercial fishing permit (of any type) and a special striped bass fishing endorsement to sell their catch. They are required to file monthly trip level reports which include the name of the dealer(s) that they sell to and information describing their catch composition and catch rates.

Landings. The landings used here come from the SAFIS program. Commercial dealers bought 938,741 pounds (48,044 fish from count of commercial tags used) of striped bass in 2016 (Table 1). Most striped bass were sold in Barnstable, Bristol, Essex and Plymouth counties of Massachusetts.

Size Composition. Information from biological sampling, catch reports and voluntary logs is used to characterize disposition of the catch, catch weight, and size composition by catch category. Data from 700 fish sampled from the 2016 commercial harvest and 2000 DMF diet study were used to construct a length-weight equation to estimate weight-at-size for individual bass. The following geometric regression was derived:

$$\log_{10}(W) = -3.451 + 2.998 * \log_{10}(L),$$
$$RMS = 0.0026$$

where W equals weight in pounds, L equals total length in inches, and RMS is the residual mean square error. This equation was used to estimate the arithmetic average weight for a given length by back-transforming the predicted weight as follows:

$$W = 10^{(-3.451 + 2.998 * \log_{10}(L) + RMS/2)}$$

Size composition of the commercial harvest is presented in Appendix Table 1.

Age and Sex Composition.. Seven hundred fish sampled from the 2016 commercial harvest were used to sex and age the harvested fish. Age composition of harvest fish was estimated from a sub-sample of 681 fish. Age was determined from scales, and sex was determined by visual inspection of gonadal tissue (Sykes Method). Age of harvested fish ranged from 6 to 18 years. About 78% of the sub-sample consisted of individuals from the 2004-2008 year classes (ages 8-12) (Figure 1).

Estimates of Total Catch and Harvest Rates. Estimates of harvest rates (pounds of fish harvested per hour) for the commercial fishery were developed in order to provide an index that may be indicative of fishing success. In 2011, *MarineFisheries* switched to trip-level reporting. Significant information has been lost due to the generalization of the report to cover all fisheries in Massachusetts. The only information now available is daily total hours fished, pounds of fish sold and consumed, and area fished. This information was used under a generalized linear model (GLM) framework to generate standardized indices (Hilborn and Walter, 1992). Each record represented the summarization of a permit's pounds harvested and hours fished by year, month, and area fished reduced to 4 regions (Cape Cod Canal, Southern MA, Cape Cod Bay, North MA). Only data from July-August were used to constraint analyses to the most recent duration of the fishing season. The harvest rates for each record was calculated by dividing the total pounds caught by the total number of hours fished. The harvest rate was standardized using the GLM model

$$\ln(y) = a + \sum_{i=1}^{n} b_i X_i + e$$

where y is the observed total catch or harvest rate, a is the intercept, b_i is the slope coefficient of the ith factor, X_i is the ith categorical variable, and e is the error term. Any variable not significant at $\alpha = 0.05$ with type-II (partial) sum of squares was dropped from the initial GLM model and the analysis was repeated. First-order interactions were not considered in the analyses. The back-transformed geometric mean for each year was estimated by

$$\hat{y} = \exp(LSM)$$

where LSM is the least-squares natural log mean of each year.

Results of the GLM analyses of harvest rates are shown in Appendix Table 2. Although factors were significant, the variables accounted for only about 7% of the total variation in harvest rates.

Harvest rates steadily increased after 1999, peaked in 2004, dropped through 2008, increased slightly through 2010 and then dramatically increased in 2011 and remained at high levels in 2012, dropped through 2014 and increased through 2016 (Figure 2A). The dramatic increase in harvest rates for 2011 and 2012 is attributed to large increases in harvest rates by fishers in Cape Cod Bay and southern Massachusetts (Figure 2B). The reason for the increase was due to atypical, large concentrations of striped bass (likely attracted to large aggregations of sand lance of sand lance in the area) off Cape Cod, particularly off Chatham in

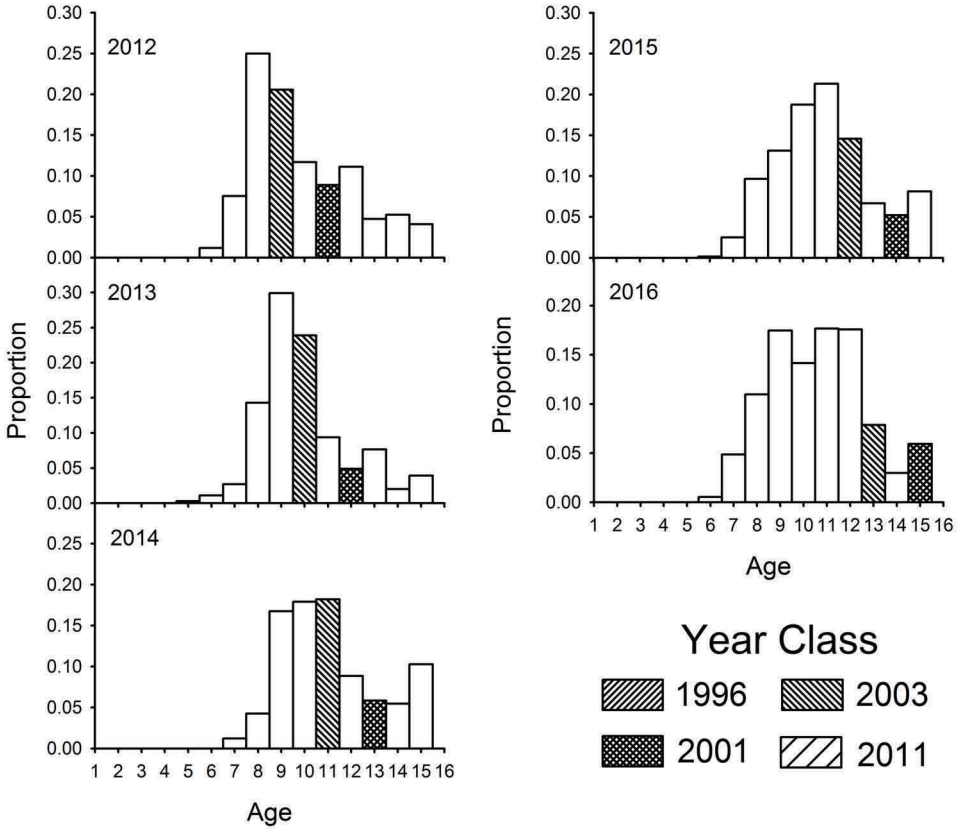

Figure 1. Age composition (proportion) of harvest from the Massachusetts commercial fishery. The large 1996, 2001, 2003 and 2011 Chesapeake Bay year-classes are highlighted.

2011 and 2012. These large aggregations likely increased the vulnerability of striped bass to capture. In 2015, catch rates in Cape Cod Bay and northern Massachusetts increased substantially likely the result of a shift in distribution of aggregated striped bass. Average catch rates dropped in all areas in 2016.

Recreational Fishery in 2015

Season: None

Daily Bag Limit: One fish per person

Allowable Gear Type: Hook and Line

Minimum Size: 28 inches total length

Licensing and Reporting Requirements: A recreational fishing permit is required in MA state waters.

Harvest levels: Harvest (A+B1) and total catch (A+B1+B2) estimates (Table 2) were provided by the NMFS MRIP. The MRIP estimates of total catch (including fish released alive) in 2016 was 2,356,558 striped bass, which is a 37.2% increase compared to the 2015 estimate (Table 2). The estimate of total harvest in 2016 was 131,793 fish, which is a 22.8% decrease in harvest compared to 2015. Total pounds harvested was over 2.2 million in 2016 (Table 2).

Size Composition. The length distributions of harvested and released fish were estimated from biological sampling conducted by the MRIP program in Massachusetts and from the volunteer Sportfish Data Collection Team (SADCT) angler program conducted by the Division. Volunteer recreational anglers were solicited to collect length and scale samples from striped bass that they captured each month (May-October). Each person was asked to collect a minimum of 5 scales from at least 10 fish per month and record the disposition of each fish (released or harvested) and fishing mode. Over 1,700 samples were received from 59 anglers

in 2016. The size frequencies of measured fish are shown in Figure 3 by disposition and mode. The size frequency of released fishes was used to allocate MRIP release numbers by mode among size classes. Numbers-at-length and weight-at-length data by disposition are summarized in Appendix Table 3.

Age Composition. A sub-sample of 713 fish from the volunteer angler survey was aged and combined with commercial and tagging samples to produce an age-length key used to convert the MRIP and MA volunteer angler size distributions into age classes. Recreational samples were selected using a weighted random design based on the total number of striped bass caught in each wave and mode stratum (as determined by MRIP). Recreational harvest and total removals in 2016 catches of striped bass were comprised mostly of the 2011 and 2014 year-classes. (Figure 4).

Trends in Catch Rates. To examine trends in recreational angler catches, standardized catch rates (total number of fish per trip) for striped bass were calculated for all fish caught using a delta-Gamma model (Lo et al., 1992; Stefansson, 1996) which adjusts trip catches for the effects of year, wave, county, area fished, mode fished, and time spent fishing. A delta-Gamma model was selected as the best approach to estimate year effects after examination of model dispersion (Terceiro, 2003) and standardized residual deviance plots (McCullagh and Nelder, 1989). In the delta-Gamma model, catch data is decomposed into catch success/failure and positive catch components. Each component is analyzed separately using appropriate statistical techniques and then the statistical models are recombined to obtain year estimates. The catch success/failure was modeled as a binary response to the categorical variables using multiple logistic regression:

$$\text{logit}(p) = \log(p/1-p) = a + \sum_{i=1}^{n} b_i X_i + e$$

where p is the probability of catching a fish, a is the intercept, b_i is the slope coefficient of the ith factor, X_i is the ith categorical variable, and e is the error term. The function *glm* in *R* was used to estimate parameters, and goodness-of-fit was assessed using partial and empirical probability plots.

Positive catches were modeled assuming a Gamma error distribution with a log link using function *glm* in *R:*

$$y = \exp^{(a+\sum_{i=1}^{n} b_i X_i)} + e$$

where y is the observed positive catch, b_i ,and X_i are the same symbols as defined earlier, and e is the Gamma error term. Any variable not significant at α=0.05 dropped from the initial GLM model and the analysis was repeated. First-order interactions were considered in the initial analyses but it was not

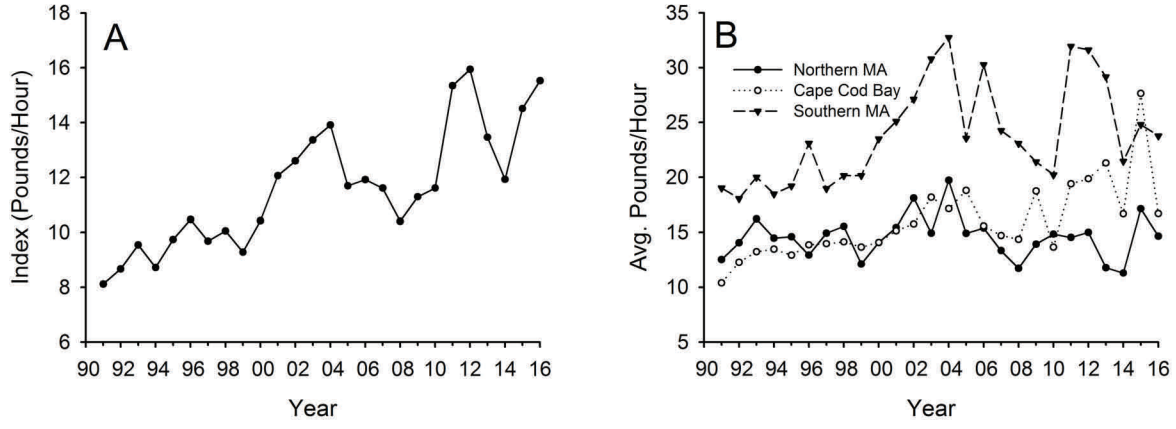

Figure 2. A) Harvest index (standardized pounds/hour) and B) average harvest rates by area for the Massachusetts commercial striped bass fishery, 1990-2016.

Table 2. MRIP estimates of striped bass harvest, releases, and total catch in Massachusetts.

	Harvest (A+B1)		Released (B2)	Total (A+B1+B2)
Year	Numbers	Weight (lbs)	Numbers	Numbers
1986	29,434	298,816	442,298	471,732
1987	10,807	269,459	93,660	104,467
1988	21,050	421,317	209,632	230,682
1989	13,044	295,227	193,067	206,111
1990	20,515	319,092	339,511	360,026
1991	20,799	440,605	448,735	469,534
1992	57,084	972,116	779,814	836,898
1993	58,511	1,113,446	833,566	892,077
1994	74,538	1,686,049	2,102,514	2,177,052
1995	73,806	1,504,390	3,280,882	3,354,688
1996	68,300	1,291,706	3,269,746	3,338,046
1997	199,373	2,891,970	5,417,751	5,617,124
1998	207,952	2,973,456	7,184,358	7,392,310
1999	126,755	1,822,818	4,576,208	4,702,963
2000	181,295	2,618,216	7,382,031	7,563,326
2001	288,032	3,644,561	5,410,899	5,698,930
2002	308,749	4,304,883	5,718,984	6,027,733
2003	407,100	4,889,035	4,361,710	4,768,810
2004	445,745	6,235,558	4,979,075	5,424,820
2005	340,742	5,119,345	3,988,679	4,329,421
2006	314,988	4,861,391	7,809,777	8,124,765
2007	315,409	5,099,862	5,331,470	5,646,879
2008	377,959	5,720,651	3,649,415	4,027,374
2009	344,401	4,795,791	2,282,601	2,627,002
2010	341,046	4,277,990	1,671,437	2,012,483
2011	255,507	3,504,603	973,192	1,228,699
2012	377,931	5,441,893	989,509	1,367,440
2013	282,170	3,899,919	1,690,888	1,973,058
2014	253,877	4,056,799	1,762,718	2,016,595
2015	170,770	2,701,724	1,546,094	1,716,864
2016	131,793	2,048,238	2,224,765	2,356,558

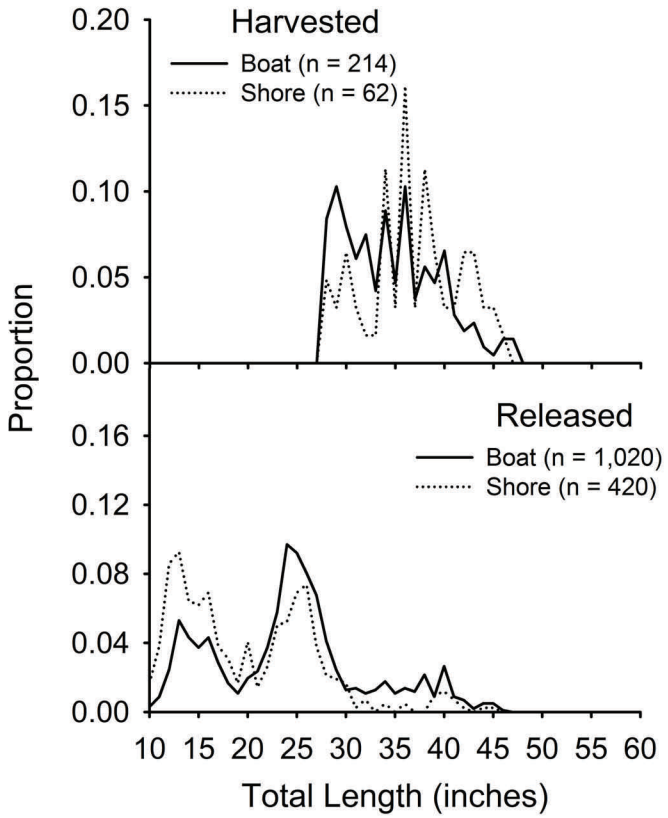

Figure 3. Sizes of striped bass caught by volunteer recreational anglers in 2016 by disposition and fishing mode.

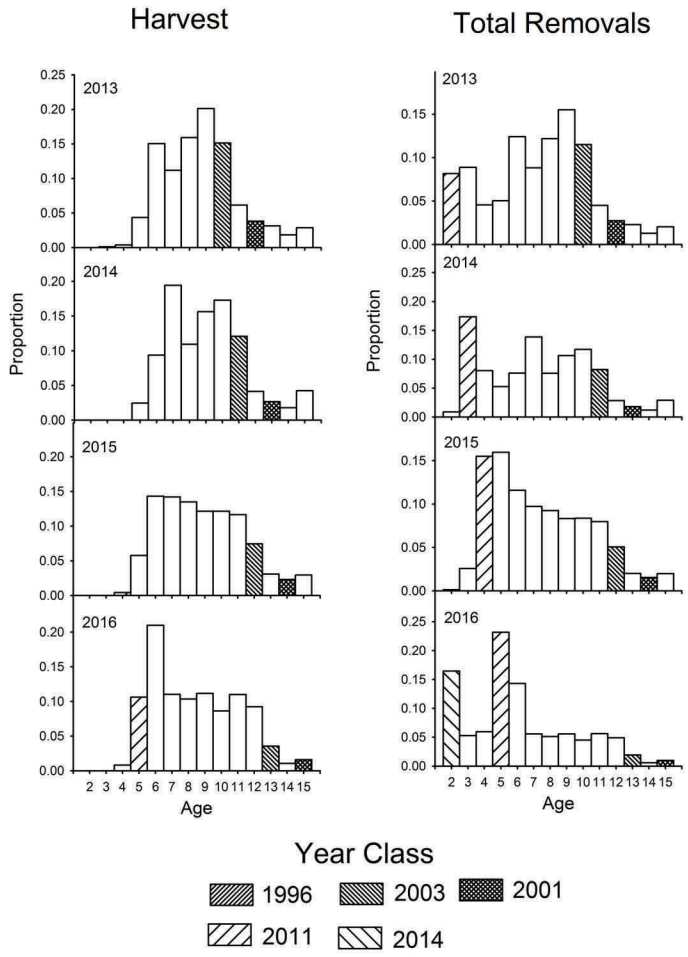

Figure 4. Age composition (proportion) of harvest and total removal (harvest plus dead releases) from the Massachusetts recreational fishery. The large 1996, 2001, 2003 and 2011 year-classes from Chesapeake Bay are highlighted. The 2014 year-class may be from the Hudson River.

always possible to generate annual means by the least-square methods with some interactions included (see Searle et al., 1980); therefore, only main effects were considered.

The annual index of striped bass total catch per trip was estimated by combining the two component models. The estimate in year *i* from the models is given by

$$\hat{I}_i = \hat{p}_i * \hat{y}_i$$

where p_i and y_i are the predicted annual responses from the least-squares mean estimates from the logistic and GLM models. Only data for those anglers who said they targeted striped bass were used in the analyses.

Results of the delta-Gamma model analyses are given in Appendix Tables 4A and 4B for 1987-2016. Standardized catch rates for striped bass in Massachusetts waters increased from 1993 to 1998, declined through 2003, but increased in 2004 and 2005 (Fig. 5). In 2006, catch rates jumped dramatically as the large 2003 year-class became vulnerable to the fishery. Catch rates declined through 2011, but began increasing in 2012 and dramatically increased in 2016 as the 2011 and 2014 year-classes became vulnerable to the fishery (Fig. 5).

Characterization of Losses

Losses due to hook-and-release calculated by using a release mortality rate of 0.09. Losses due to hook-and-release were 200,228 fish (about 1.2 million pounds) (Table 3).

Bycatch in Other Fisheries

During 1994, *MarineFisheries* sea-sampling efforts identified striped bass as by-catch in a Nantucket Sound springtime trawl fishery directed

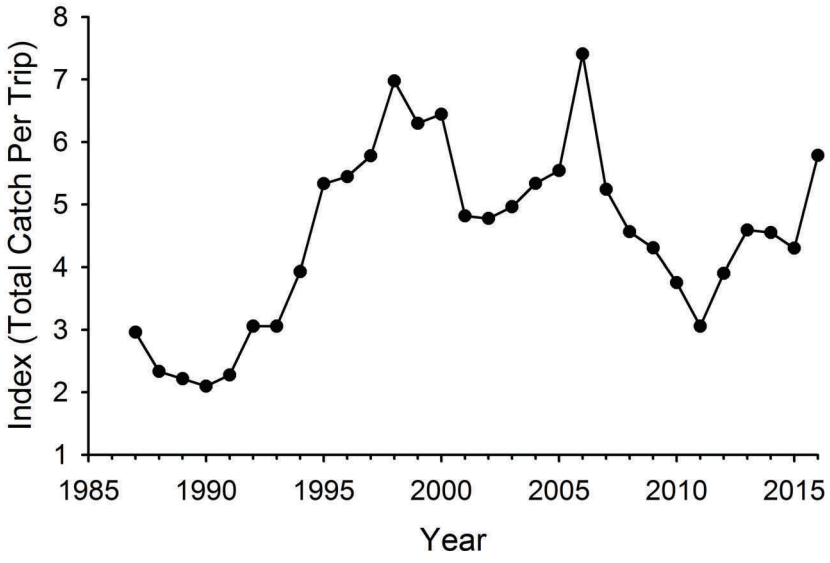

Figure 5. Standardized total catch rates (total number of fish caught per trip) of the recreational fishery for striped bass in Massachusetts waters, 1987-2015.

at long-finned squid (*Loligo pealei*). The bycatch estimate was about 3,100 fish (17,600 pounds). Anecdotal information was also reported which suggested that a single tow could land up to 19,000 pounds. Division personnel sampled this fishery at sea during 1995-2000 and observed only incidental catches of striped bass. Limited sampling and low catch rates make it unreasonable to extrapolate sample information. *MarineFisheries* will continue to monitor potential sources of striped bass by-catch during 2017.

Estimated Total Losses in 2016

Total estimated loss (commercial harvest plus recreational harvest plus recreational dead releases) of striped bass during 2016 was 380,066 fish weighing over 4.1 million pounds pounds (Table 3).

Removals-At-Age Matrix in 2016

The removals (numbers) by the recreational and commercial fisheries are apportioned by age and mortality source in Table 4. The 2014 (age 2 possibly from the Hudson River), 2011 (age 5) and 2010 (age 6) year-classes incurred the highest losses in 2016 (Figure 6).

Age-Length Relationship

A von Bertalanffy growth model was fitted to age (years) and total length (inches) data from samples collected in the tagging study, the recreational fishery, and commercial fishery from

Table 3. Estimates of striped bass losses occurring in Massachusetts waters during 2016.

FISHERY	NUMBER	POUNDS	MEAN WT.
Commercial			
Harvest	48,044	938,741	19.5
Recreational			
Harvest	131,793	2,048,238	15.5
Release Mortality	200,229	1,174,665	5.9
Total	380,066	4,161,644	

Table 4. Massachusetts striped bass removals-at-age matrix of 2016 by source.

	Recreational		Commercial	
Age	Release Mortality	Harvest	Harvest	Total
2	54643	0	0	54,643
3	17594	0	0	17,594
4	18719	1,076	0	19,794
5	63009	14,001	0	77,009
6	19900	27,635	262	47,797
7	3995	14,514	2339	20,848
8	3416	13,641	5265	22,323
9	3778	14,695	8385	26,858
10	3561	11,371	6797	21,730
11	4217	14,492	8492	27,201
12	4100	12,184	8448	24,732
13	1673	4,680	3775	10,129
14	525	1,388	1426	3,339
15+	1098	2,114	2855	6,068

2016. The resulting equation and predicted relationship are shown in Figure 7.

Required Fishery-Independent Monitoring Programs

Massachusetts Tagging Study

DMF joined the Striped Bass Cooperative State-Federal Coast-wide Tagging Study in 1991. The study's primary objective has been to develop an integrated database of tag releases and recoveries that will provide current information related to striped bass mortality and migration rates. The Massachusetts tagging effort has focused on the tag and release of large fish that reach coast-wide legal sizes. To accomplish this job, DMF contracts several select charter boat captains to take DMF personnel on board to tag and release their catch during regularly scheduled fishing trips. Fish are caught in fall by trolling artificial baits in shoal areas around Nantucket Island (Figure 8). Floy internal anchor tags provided by the USFWS are used. Total length of each fish is recorded. Scales are removed from each fish for aging. The release data are made available to the Annapolis, Maryland office of the USFWS, which coordinates regional tagging programs of state-federal participants.

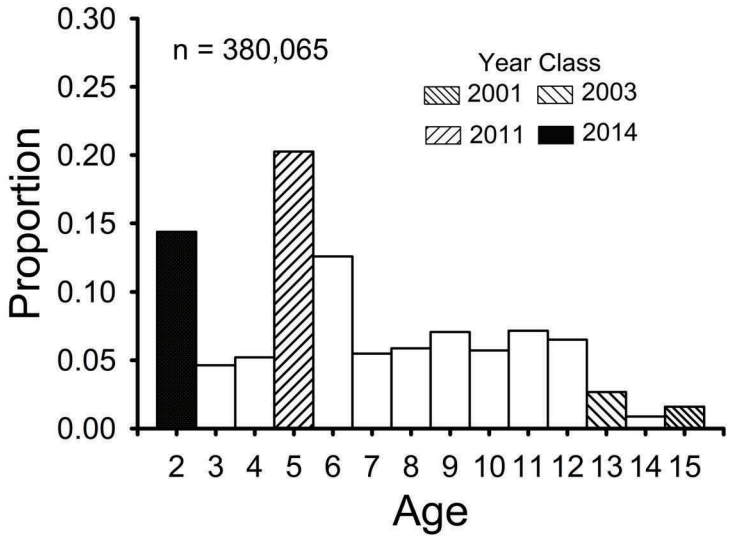

Figure 6. Proportion of striped bass total removals (commercial plus recreational) in 2016 by age. The 2001, 2003, 2011 year-classes from Chesapeake Bay and the 2014 year-class from Hudson River are indicated.

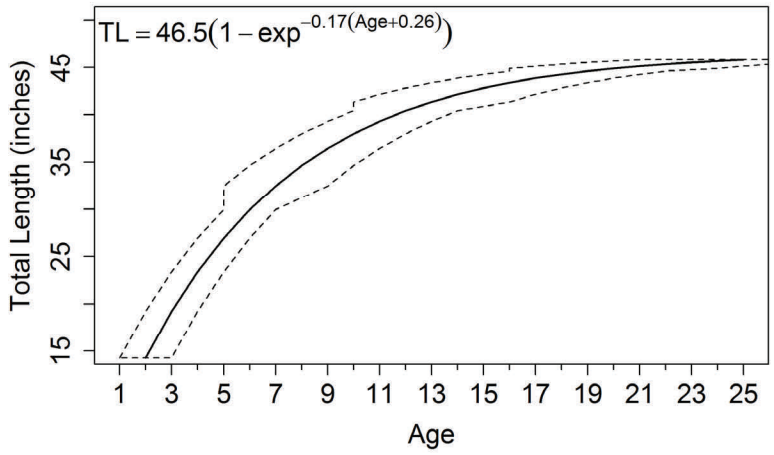

Figure 7. Mean length-age relationship (solid line) for striped bass captured in Massachusetts. Dotted lines represent the minimum and maximum ages found at a given length.

Summary statistics compiled since the start of this study are shown in Table 5. Striped bass recaptured in 2012-2016 were reported from coastal waters in North Carolina through Maine (Figure 9).

Planned Management Programs in 2017

Regulations

Massachusetts' recreational bag and minimum size limits will remain at 1 fish per day and 28-inches total length, respectively. For the commercial fishery, minimum size limit will remain at 34-inches and the quota will be 800,886 pounds because of the overage in 2016. The commercial fishery quota will be monitored using the SAFIS system. All monitoring programs will continue in 2017.

Acknowledgements

The collection and quality of striped bass data would suffer greatly without the efforts of many DMF employees. Staff of the Fisheries Statistics

Table 5. Massachusetts tag summary statistics. SD = standard deviation.

			Number	Ave.	Ave.	SD	SD	Length Range			
Year	Trips	Boats	Tagged	Length (mm)	Length (in)	(mm)	(in)	Min (mm)	Min (in)	Max (mm)	Max (in)
1991	17	4	388	817	32.2	106.4	4.2	534	21.0	1300	51.2
1992	29	3	899	798	31.4	125.9	5.0	524	20.6	1267	49.9
1993	15	2	678	784	30.9	125.0	4.9	515	20.3	1210	47.6
1994	13	2	377	735	28.9	93.2	3.7	548	21.6	1028	40.5
1995	11	2	449	767	30.2	110.2	4.3	470	18.5	1178	46.4
1996	8	2	203	748	29.4	64.1	2.5	541	21.3	1077	42.4
1997	10	2	321	773	30.4	114.7	4.5	485	19.1	1090	42.9
1998	12	2	382	797	31.4	93.8	3.7	597	23.5	1055	41.5
1999	16	2	471	777	30.6	95.5	3.8	594	23.4	1108	43.6
2000	25	4	1095	752	29.6	102.6	4.0	510	20.1	1204	47.4
2001	14	3	456	786	30.9	102.5	4.0	503	19.8	1110	43.7
2002	12	3	239	764	30.1	103.6	4.1	487	19.2	1060	41.7
2003	15	3	655	825	32.5	92.1	3.6	602	23.7	1204	47.4
2004	25	7	784	707	27.8	193.1	7.6	316	12.4	1164	45.8
2005	19	4	752	726	28.6	210.5	8.3	299	11.8	1114	43.9
2006	11	4	390	813	32.0	94.2	3.7	565	22.2	1114	43.9
2007	16	3	530	848	33.4	105.2	4.1	600	23.6	1225	48.2
2008	13	2	456	821	32.3	104.6	4.1	530	20.9	1202	47.3
2009	15	3	501	840	33.1	101.8	4.0	572	22.5	1146	45.1
2010	13	3	329	825	32.5	84.0	3.3	668	26.3	1095	43.1
2011	15	3	504	831	32.7	91.9	3.6	580	22.8	1174	46.2
2012	15	3	643	852	33.5	87.7	3.5	524	20.6	1203	47.4
2013	15	3	487	854	33.6	92.2	3.63	617	24.3	1145	45.1
2014	15	3	455	876	34.5	98.8	3.89	536	21.1	1203	47.4
2015	15	3	348	857	33.7	90.9	3.58	597	23.5	1063	41.9
2016	14	3	711	788	31.0	108.2	4.26	523	20.6	1065	41.9

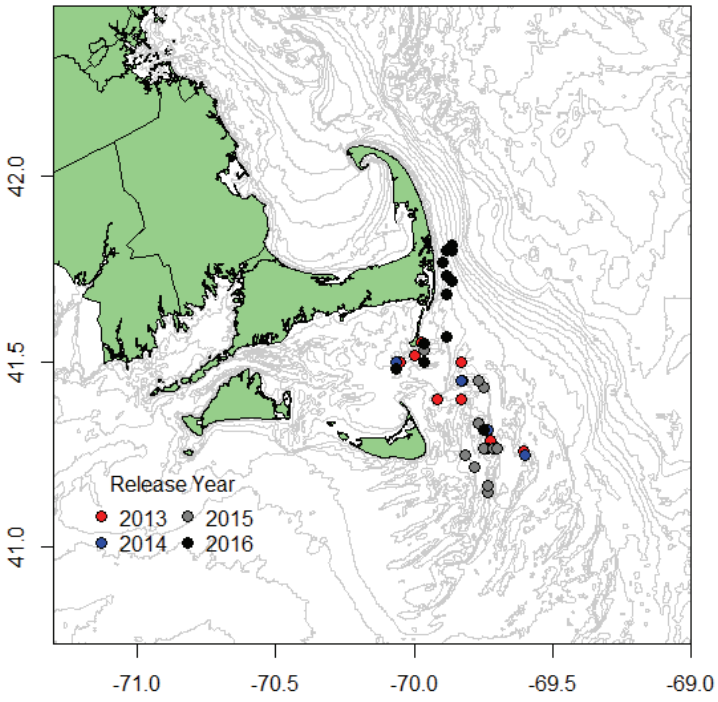

Figure 8. Map of DMF fall tagging locations during 2013-2016.

section collected, entered, and compiled all commercial data. Kim Trull coordinated the volunteer recreational angler data collection program, entered scale envelope data, and prepared data for analysis. Scott Elzey, Elise Koob, Collin Farrell and Kim Trull prepared and aged scale samples. John Boardman, Nick Buchan, and Nicole Ward conducted the commercial sampling of stripers. John Boardman also coordinated and conducted the USFWS cooperative tagging study. Funding for this effort was provided by the Massachusetts Division of Marine Fisheries and Sportfish Restoration Funds Grants F-57-R and F-48-R.

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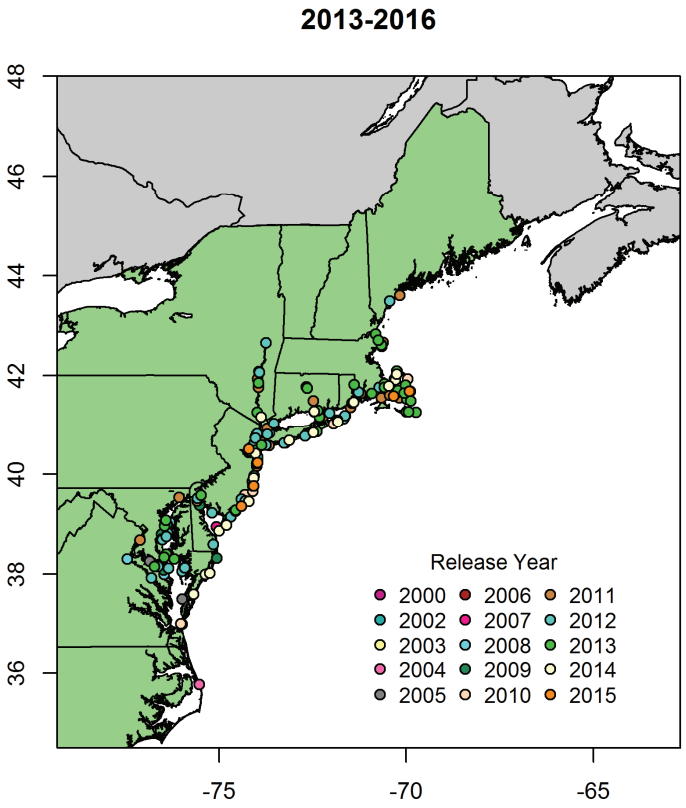

Figure 9. Map of recovery locations of *MarineFisheries* striped bass during 2013-2016 by release year.

Appendix Table 1. Estimated size distribution of the Massachusetts commercial striped bass harvest (numbers and weight of fish) by total length (TL in inches) in 2016.

TL (in.)	Number	% Number	Weight (lbs)	% Weight
11	0	0.00	0	0.00
12	0	0.00	0	0.00
13	0	0.00	0	0.00
14	0	0.00	0	0.00
15	0	0.00	0	0.00
16	0	0.00	0	0.00
17	0	0.00	0	0.00
18	0	0.00	0	0.00
19	0	0.00	0	0.00
20	0	0.00	0	0.00
21	0	0.00	0	0.00
22	0	0.00	0	0.00
23	0	0.00	0	0.00
24	0	0.00	0	0.00
25	0	0.00	0	0.00
26	0	0.00	0	0.00
27	0	0.00	0	0.00
28	0	0.00	0	0.00
29	0	0.00	0	0.00
30	0	0.00	0	0.00
31	0	0.00	0	0.00
32	0	0.00	0	0.00
33	0	0.00	0	0.00
34	2,750	5.72	35,443	3.78
35	4,681	9.74	65,790	7.01
36	5,074	10.56	77,605	8.27
37	5,190	10.80	86,158	9.18
38	5,474	11.39	98,435	10.49
39	5,837	12.15	113,460	12.09
40	5,462	11.37	114,547	12.20
41	4,297	8.94	97,017	10.33
42	2,883	6.00	69,974	7.45
43	2,253	4.69	58,680	6.25
44	1,037	2.16	28,937	3.08
45	3,106	6.46	92,695	9.87
Total	48,044		938,741	
Avg. Size	38.8		19.5	

Appendix Table 2. Results of the GLM analyses of total catch rates (pounds/hour) for the commercial striped bass fishery, 1991-2016.

Analysis of Deviance Table (Type III tests)

	SS	Df	F	Pr(>F)	
YEAR	1774	25	69.7493	< 2.2e-16	***
MONTH	8	1	8.2438	0.004091	**
AREA	2384	2	1171.9452	< 2.2e-16	***
Residuals	61703	60663			

LSMEANS

1991	8.119332
1992	8.670754
1993	9.541720
1994	8.721681
1995	9.738671
1996	10.466369
1997	9.681569
1998	10.053486
1999	9.282497
2000	10.424690
2001	12.060023
2002	12.596939
2003	13.366870
2004	13.913215
2005	11.689872
2006	11.915996
2007	11.609195
2008	10.403740
2009	11.290936
2010	11.607339
2011	15.345493
2012	15.938786
2013	13.460247
2014	11.927511
2015	14.511259
2016	15.523414

Appendix Table 3. Estimated size distribution of the Massachusetts recreational striped bass catch (numbers and weight of fish) in 2016 by disposition.

	Harvested				Released				Total			
TL (in.)	Number	% Number	Weight	% Weight	Number	% Number	Weight	% Weight	Number	% Number	Weight	% Weight
9	0	0.0	0	0.0	8,069	0.4	2,031	0.0	8,069	0.3	2,031	0.0
10	0	0.0	0	0.0	13,969	0.6	4,822	0.0	13,969	0.6	4,822	0.0
11	0	0.0	0	0.0	39,389	1.8	18,094	0.1	39,389	1.7	18,094	0.1
12	0	0.0	0	0.0	93,613	4.2	55,819	0.4	93,613	4.0	55,819	0.4
13	0	0.0	0	0.0	147,651	6.6	111,919	0.9	147,651	6.3	111,919	0.7
14	0	0.0	0	0.0	110,344	5.0	104,450	0.8	110,344	4.7	104,450	0.7
15	0	0.0	0	0.0	99,391	4.5	115,701	0.9	99,391	4.2	115,701	0.8
16	0	0.0	0	0.0	109,525	4.9	154,717	1.2	109,525	4.6	154,717	1.0
17	0	0.0	0	0.0	66,473	3.0	112,617	0.9	66,473	2.8	112,617	0.7
18	0	0.0	0	0.0	47,984	2.2	96,489	0.7	47,984	2.0	96,489	0.6
19	0	0.0	0	0.0	27,603	1.2	65,274	0.5	27,603	1.2	65,274	0.4
20	0	0.0	0	0.0	56,989	2.6	157,166	1.2	56,989	2.4	157,166	1.0
21	0	0.0	0	0.0	42,878	1.9	136,877	1.0	42,878	1.8	136,877	0.9
22	0	0.0	0	0.0	68,977	3.1	253,146	1.9	68,977	2.9	253,146	1.7
23	0	0.0	0	0.0	116,464	5.2	488,357	3.7	116,464	4.9	488,357	3.2
24	0	0.0	0	0.0	181,822	8.2	866,177	6.6	181,822	7.7	866,177	5.7
25	0	0.0	0	0.0	191,157	8.6	1,029,207	7.9	191,157	8.1	1,029,207	6.8
26	0	0.0	0	0.0	179,610	8.1	1,087,703	8.3	179,610	7.6	1,087,703	7.2
27	0	0.0	0	0.0	128,951	5.8	874,469	6.7	128,951	5.5	874,469	5.8
28	7,489	5.7	56,639	2.8	86,619	3.9	655,067	5.0	94,108	4.0	711,706	4.7
29	11,557	8.8	97,099	4.7	53,054	2.4	445,740	3.4	64,611	2.7	542,839	3.6
30	16,840	12.8	156,621	7.6	32,737	1.5	304,469	2.3	49,577	2.1	461,090	3.1
31	5,721	4.3	58,706	2.9	23,621	1.1	242,380	1.9	29,342	1.2	301,086	2.0
32	7,066	5.4	79,747	3.9	19,033	0.9	214,805	1.6	26,099	1.1	294,552	2.0
33	8,618	6.5	106,663	5.2	19,855	0.9	245,739	1.9	28,473	1.2	352,402	2.3
34	10,099	7.7	136,689	6.7	31,466	1.4	425,907	3.3	41,565	1.8	562,596	3.7
35	4,478	3.4	66,116	3.2	18,262	0.8	269,628	2.1	22,740	1.0	335,744	2.2
36	11,310	8.6	181,698	8.9	25,367	1.1	407,536	3.1	36,677	1.6	589,234	3.9
37	6,708	5.1	116,995	5.7	19,505	0.9	340,187	2.6	26,213	1.1	457,182	3.0
38	4,569	3.5	86,313	4.2	34,853	1.6	658,469	5.0	39,422	1.7	744,782	4.9
39	10,886	8.3	222,327	10.9	19,843	0.9	405,251	3.1	30,729	1.3	627,578	4.2
40	5,929	4.5	130,628	6.4	50,573	2.3	1,114,295	8.5	56,502	2.4	1,244,923	8.2
41	9,726	7.4	230,761	11.3	19,923	0.9	472,702	3.6	29,649	1.3	703,463	4.7
42	2,430	1.8	61,982	3.0	13,985	0.6	356,674	2.7	16,415	0.7	418,656	2.8
43	3,010	2.3	82,374	4.0	3,419	0.2	93,572	0.7	6,429	0.3	175,946	1.2
44	1,215	0.9	35,629	1.7	10,682	0.5	313,208	2.4	11,897	0.5	348,837	2.3
45	636	0.5	19,935	1.0	9,827	0.4	308,221	2.4	10,463	0.4	328,155	2.2
46	1,767	1.3	59,187	2.9	1,282	0.1	42,948	0.3	3,049	0.1	102,135	0.7
47	1,739	1.3	62,128	3.0	0	0.0	0	0.0	1,739	0.1	62,128	0.4
48	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
49	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
50	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
51	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
52	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
53	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
54	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
55	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
56	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Total	131,792		2,048,238		2,224,765		13,051,832		2,356,557		15,100,070	
Avg. Size	34.9				23.1				23.8			

Appendix Table 4A. Results of the Gamma regression analysis of MRFSS striped bass catch positive catches.

```
Analysis of Deviance Table (Type III tests)

Response: tot_fish
          LR Chisq Df Pr(>Chisq)
year        546.53 29  < 2.2e-16 ***
area_x       48.70  2  2.662e-11 ***
mode_fx     453.43  2  < 2.2e-16 ***
wave        403.05  3  < 2.2e-16 ***
cnty        143.84  7  < 2.2e-16 ***
ffdays12c   645.27 12  < 2.2e-16 ***
hours      1067.23 11  < 2.2e-16 ***
Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)   0.295440   0.230266   1.283 0.199491
year1988     -0.153021   0.255117  -0.600 0.548641
year1989     -0.234376   0.248729  -0.942 0.346051
year1990     -0.229387   0.239719  -0.957 0.338627
year1991     -0.084047   0.239208  -0.351 0.725324
year1992      0.118008   0.232473   0.508 0.611722
year1993     -0.036740   0.231605  -0.159 0.873960
year1994      0.035311   0.229134   0.154 0.877528
year1995      0.256504   0.228372   1.123 0.261368
year1996      0.266383   0.228648   1.165 0.244016
year1997      0.330431   0.228140   1.448 0.147524
year1998      0.415243   0.227694   1.824 0.068210 .
year1999      0.361582   0.227959   1.586 0.112713
year2000      0.404648   0.228381   1.772 0.076437 .
year2001      0.162833   0.228177   0.714 0.475464
year2002      0.142249   0.228682   0.622 0.533923
year2003      0.207486   0.228652   0.907 0.364188
year2004      0.257458   0.229249   1.123 0.261427
year2005      0.266730   0.229532   1.162 0.245221
year2006      0.501797   0.228612   2.195 0.028175 *
year2007      0.228172   0.229194   0.996 0.319482
year2008      0.137307   0.230510   0.596 0.551404
year2009      0.094308   0.230019   0.410 0.681809
year2010      0.031570   0.231352   0.136 0.891461
year2011     -0.128375   0.232185  -0.553 0.580336
year2012     -0.125209   0.232460  -0.539 0.590149
year2013     -0.055946   0.229367  -0.244 0.807300
year2014      0.004389   0.230692   0.019 0.984820
year2015     -0.026842   0.229913  -0.117 0.907059
year2016      0.190123   0.230482   0.825 0.409440
area_x2      -0.041862   0.025243  -1.658 0.097255 .
area_x5       0.096926   0.017062   5.681 1.36e-08 ***
mode_fx6      0.353116   0.031871  11.080  < 2e-16 ***
mode_fx7      0.483909   0.021794  22.204  < 2e-16 ***
wave4        -0.309163   0.016424 -18.824  < 2e-16 ***
wave5        -0.177514   0.021086  -8.419  < 2e-16 ***
wave6         1.168218   0.225519   5.180 2.23e-07 ***
cnty19       -0.115108   0.068927  -1.670 0.094930 .
cnty21       -0.016581   0.040558  -0.409 0.682680
cnty23       -0.034873   0.024461  -1.426 0.153980
cnty25       -0.307841   0.060034  -5.128 2.95e-07 ***
cnty5        -0.121523   0.036465  -3.333 0.000862 ***
cnty7        -0.305985   0.047944  -6.382 1.78e-10 ***
cnty9         0.111770   0.018791   5.948 2.75e-09 ***
ffdays12c10   0.061304   0.023362   2.624 0.008692 **
ffdays12c20   0.195792   0.024077   8.132 4.41e-16 ***
ffdays12c30   0.208665   0.027955   7.464 8.64e-14 ***
ffdays12c40   0.351602   0.034296  10.252  < 2e-16 ***
ffdays12c50   0.387652   0.030123  12.869  < 2e-16 ***
```

Appendix 4A cont'd.

Year	LSMEANS
1987	5.596798
1988	4.802678
1989	4.427426
1990	4.449569
1991	5.145628
1992	6.297818
1993	5.394903
1994	5.797956
1995	7.233326
1996	7.305133
1997	7.788328
1998	8.477685
1999	8.034759
2000	8.388338
2001	6.586536
2002	6.452345
2003	6.887310
2004	7.240225
2005	7.307675
2006	9.244153
2007	7.031265
2008	6.420538
2009	6.150311
2010	5.776305
2011	4.922514
2012	4.938123
2013	5.292279
2014	5.621419
2015	5.448565
2016	6.768757

Appendix Table 4B. Results of the logistic regression analysis of MRFSS striped bass success/failure.

```
Analysis of Deviance Table (Type III tests)

Response: Presence/Absence
          LR Chisq Df Pr(>Chisq)
year        2253.3 29  < 2.2e-16 ***
area_x       269.4  2  < 2.2e-16 ***
mode_fx     4188.7  2  < 2.2e-16 ***
wave         567.7  3  < 2.2e-16 ***
cnty         534.4  7  < 2.2e-16 ***
ffdays12c   1044.5 12  < 2.2e-16 ***
hours       2852.2 11  < 2.2e-16 ***



Coefficients:
             Estimate Std. Error z value Pr(>|z|)
(Intercept)  -3.56004    0.24734 -14.393  < 2e-16 ***
year1988     -0.17308    0.27037  -0.640 0.522060
year1989     -0.11306    0.26698  -0.423 0.671956
year1990     -0.22972    0.25620  -0.897 0.369910
year1991     -0.34865    0.25498  -1.367 0.171516
year1992     -0.17445    0.24924  -0.700 0.483988
year1993      0.15173    0.24842   0.611 0.541350
year1994      0.62734    0.24650   2.545 0.010928 *
year1995      0.91465    0.24579   3.721 0.000198 ***
year1996      0.95845    0.24622   3.893 9.92e-05 ***
year1997      0.93899    0.24549   3.825 0.000131 ***
year1998      1.41963    0.24544   5.784 7.29e-09 ***
year1999      1.17132    0.24554   4.770 1.84e-06 ***
year2000      1.08168    0.24605   4.396 1.10e-05 ***
year2001      0.88595    0.24553   3.608 0.000308 ***
year2002      0.92998    0.24641   3.774 0.000161 ***
year2003      0.83208    0.24611   3.381 0.000722 ***
year2004      0.91341    0.24752   3.690 0.000224 ***
year2005      1.02766    0.24794   4.145 3.40e-05 ***
year2006      1.27840    0.24689   5.178 2.24e-07 ***
year2007      0.95713    0.24770   3.864 0.000112 ***
year2008      0.78168    0.24887   3.141 0.001684 **
year2009      0.73183    0.24796   2.951 0.003163 **
year2010      0.50306    0.24947   2.017 0.043745 *
year2011      0.37868    0.25000   1.515 0.129853
year2012      1.21098    0.25465   4.755 1.98e-06 ***
year2013      1.76437    0.25047   7.044 1.86e-12 ***
year2014      1.33115    0.25253   5.271 1.36e-07 ***
year2015      1.20275    0.25050   4.801 1.58e-06 ***
year2016      1.65571    0.25364   6.528 6.67e-11 ***
area_x2      -0.00273    0.03271  -0.083 0.933476
area_x5       0.33068    0.02157  15.327  < 2e-16 ***
mode_fx6      2.44960    0.04347  56.356  < 2e-16 ***
mode_fx7      1.14811    0.02449  46.873  < 2e-16 ***
wave4        -0.41664    0.02199 -18.944  < 2e-16 ***
wave5        -0.54933    0.02633 -20.865  < 2e-16 ***
wave6         2.26100    0.55431   4.079 4.52e-05 ***
cnty19       -0.38546    0.07929  -4.861 1.17e-06 ***
cnty21        0.09885    0.05186   1.906 0.056637 .
cnty23       -0.14621    0.03026  -4.832 1.35e-06 ***
cnty25        0.11849    0.07384   1.605 0.108575
cnty5        -0.32154    0.04512  -7.126 1.03e-12 ***
cnty7        -0.17874    0.05739  -3.114 0.001844 **
cnty9         0.37410    0.02377  15.741  < 2e-16 ***
ffdays12c10   0.12226    0.02886   4.236 2.28e-05 ***
ffdays12c20   0.37876    0.03036  12.477  < 2e-16 ***
ffdays12c30   0.47201    0.03561  13.254  < 2e-16 ***
ffdays12c40   0.57126    0.04488  12.729  < 2e-16 ***
ffdays12c50   0.71742    0.03984  18.007  < 2e-16 ***
```

Appendix 4B cont'd.

Year	Probability
1987	0.5290034
1988	0.4857694
1989	0.5007714
1990	0.4716357
1991	0.4421343
1992	0.4854287
1993	0.5665700
1994	0.6777576
1995	0.7370688
1996	0.7454703
1997	0.7417598
1998	0.8228491
1999	0.7837173
2000	0.7681373
2001	0.7314706
2002	0.7400296
2003	0.7207583
2004	0.7368293
2005	0.7583770
2006	0.8013160
2007	0.7452200
2008	0.7105014
2009	0.7001416
2010	0.6500371
2011	0.6212418
2012	0.7903643
2013	0.8676705
2014	0.8095813
2015	0.7889971
2016	0.8546883